End of Life Effects on Seismic/LOCA Performance for the AP1000 Pressurized Water Reactor Fuel Assembly (Non-Proprietary)

September 2012

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End of Life Effects on Seismic/LOCA Performance for the AP1000 Pressurized Water Reactor Fuel Assembly

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Agenda

- Introduction and Background
  - NRC Information Notice
  - Core Reference Report (CRR) Impact
  - Previous End of Life (EOL) Studies
- EOL Effects on AP1000® Pressurized Water Reactor (PWR) Seismic/LOCA Performance
- Conservatisms with Existing Methodology
- Proposed Resolution & General Discussion

NRC I/N 2012-09 – "Irradiation Effects on Fuel Assembly Spacer Grid Crush Strength"

- In SRP 4.2 Appendix A it is assumed that increases in yield and ultimate strength due to irradiation offset the EOL effects on grid strength.
- I/N 2012-09 issued June 2012 challenges this assumption based on more recent experience.
  - *"Effects that can influence structural strength include neutron fluence (e.g., grid spring relaxation, irradiation hardening, growth, cladding creep down), corrosion, (e.g., thinning, hydrogen uptake), and operating conditions (e.g., temperature) up to the approved limits on fuel assembly burnup and service life, as applicable."*
  - Relaxation of grid springs may lower the fuel assembly stiffness resulting in lower frequencies which may impact the dynamic model results.

Core Reference Report (CRR)

- The AP1000 PWR fuel assembly seismic response tests and analyses described in the CRR follow the guidelines of SRP 4.2 Appendix A; i.e., it is based on Beginning of Life (BOL) conditions.
- In order to approve the CRR, the NRC staff has identified the need for an evaluation of EOL effects.

  "Because of spacer grid spring relaxation due to irradiation which could effect the fuel bundle stiffness and the grid strength, the NRC staff has determined the need to evaluate the fuel structural response to the seismic/LOCA load for the minimum grid strength considering irradiation effects."

Previous EOL Studies

- In August 2001 Westinghouse submitted a Topical Report (WCAP12488, Addendum 1, Rev 1) providing EOL crush test data based on:
  - Wall thinning due to oxide formation up to [ ]a,c
  - Hydrogen levels up to [ ]a,c
  - Gaps between fuel rods and grid springs up to [ ]a,c
- It was concluded that:
  - Crush strength is [ ]a,c
  - There is [ ]a,c
  - [ ]a,c
- The NRC concurred with these conclusions (SER dated Nov 21, 2001).

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Grid Crush Strength – Sensitivity to Hydrogen Concentration & Corrosion

- [
]a,c

Figure 13 from WCAP 12488-A, Addendum 1-A, Rev.1
Crush Strength vs Hydrogen Content for Un-Irradiated 5x5 Grids

a,b,c

[ ]

EOL Effects on AP1000 PWR Seismic/LOCA Performance

EOL Effects on AP1000 PWR Seismic/LOCA Performance

- Some EOL effects result in reduced margins and some result in increased margins.

EOL EFFECT	CRUSH STRENGTH (P)	IMPACT LOADS
Grid spring relaxation, cladding creep down, and grid growth resulting in gapped cells		
Corrosion resulting in material thinning due to oxide formation		
Hydrogen Pickup		
Irradiation hardening of grid material resulting in increased yield strength, increased ultimate strength, and lower ductility		
Cladding creep down and pellet swelling resulting in [ ]a,c		

a,c

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Effect of EOL Conditions

- The most significant EOL effect is gap formation between the grid springs and the fuel rods resulting in:
  - [

    ]a,c

- [

  ]a,c

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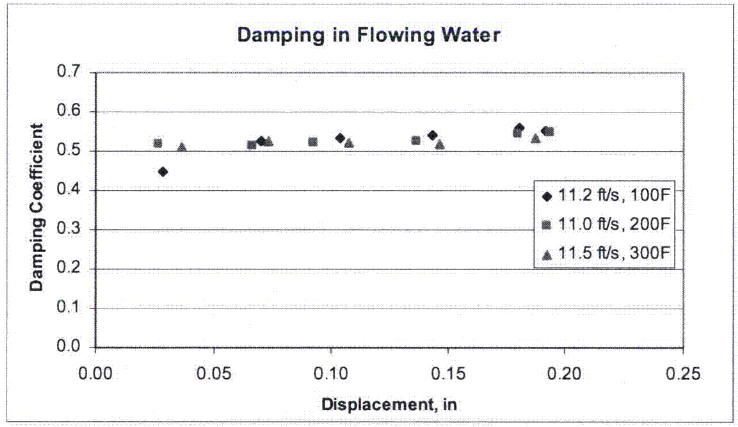
Conservatisms with Existing Methodology

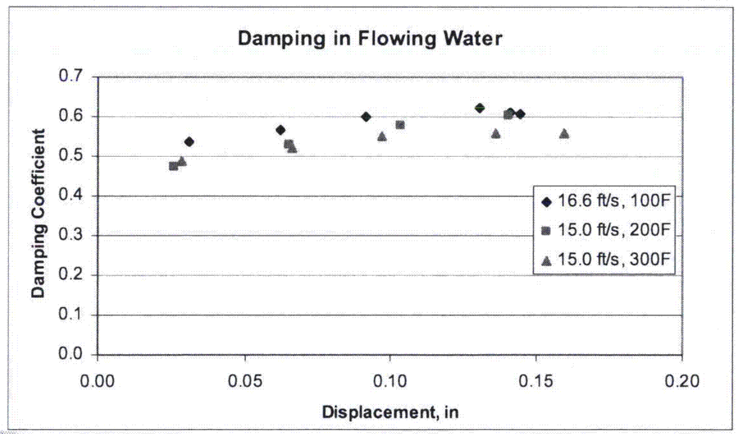
- The existing fuel assembly seismic/LOCA methodology contains some conservatisms.
- One major conservatism in the current methodology is damping. The current methodology conservatively assumes [ ]a,c fuel assembly damping based on still water conditions.
- Based on Westinghouse test data, published papers*, and industry practice, consideration of [ ]a,c fuel assembly damping due to flowing water effects can be justified.
- Other conservatisms include:
  - Fuel assembly dynamic models don't include [ ]a,c
  - AP1000 PWR seismic loads based on generic bounding seismic spectra and six soil conditions.

**ICONE14-89535, "PWR Fuel Assembly Damping Characteristics," July 2006, R.Y. Lu, Westinghouse Electric Co, LLC.*

Damping in Flowing Water – Test Results

- Damping coefficient varies from 50 to 60% for flow rates between 11 and 16.6 ft/sec for vibration amplitudes greater than 0.05 in. (typical AP1000 PWR flow rate [ ]a,c
- Damping increases with flow rate but the sensitivity is not significant in the range shown.
- Damping is not sensitive to the temperature.
- [ ]a,c damping can reasonably and conservatively be applied to AP1000 PWR.





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Proposed Resolution & General Discussion

- Quantify EOL effects:

CRUSH STRENGTH	IMPACT LOAD
Reduction in crush strength due to gapped cells.	Reduction in grid impact loads due to reduced through-grid stiffness.
	Increase in grid impact loads due to reduced fuel assembly frequencies due to effect of gapped cells.
	Reduction in grid impact loads due to increased fuel assembly frequencies due to [ ]a,c

- Reduction in impact load due consideration of [ ]a,c damping will be used to offset EOL effects.
- It is expected that the net effect will be that [ ]a,c

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